IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of	:	
Appl. No.10/625,149	:	Confirm. No. 8274
H. Downman McCarty, II Brooke Schumm III Peter Popper, Applicants	: :	 Examiner: O. Flores Sanchez
Filed: July 23, 2003	:	Group Art Unit 3724

For: **AN ANTI-SPALLING COMBINATION ON AN IMPACT TOOL WITH AN IMPROVED HOLDING SYSTEM**

DECLARATION OF JAMES L. GLANCEY, Ph.D., P.E.

My name is James L. Glancey, Ph.D., P.E. I am over the age of 18 and competent to testify. I submit this declaration in support of the allowance of "An Anti-Spalling Combination on an Impact Tool with an Improved Holding System" now pending as Serial No. 10/625,149 in the United States Patent and Trademark Office.

I am an Associate Professor in Bioresources Engineering and Mechanical Engineering at the University of Delaware in Newark, Delaware in the College of Engineering, and can be reached at 315 Spencer Lab, University of Delaware, Newark, Delaware. I hold a B.S. in Engineering from the University of Delaware and a Masters of Science and Ph.D. in Engineering from the University of California. My area of teaching is mechanical design and my area of research expertise includes the design and testing new products. I conduct extensive hands-on research with respect to hand and power tools and power machinery and have a large laboratory with test equipment at my disposal. My curriculum vitae is attached.

I have been responsible for extensive testing of the tool on which this patent application is pending, namely a chisel marketed under the trademark Hard Cap which I tested extensively and was the basis for my attached extensive article on the ergonomics and advantages of the tool.

Under the direction of co-inventor Dr. Peter Popper, a former employee of the DuPont Corporation, and Mr. McCarty, I had been directed to test materials which they believed advantageous to use for a tool cap to minimize vibration and sound emission, as well as eliminate metal spalling. As co-author and head of the project, I published, am familiar with and participated in the work associated with the attached paper Griffith M. et al, "Polymer Composite-Based Vibration and Noise Emission Controls for Hand-Struck Impact Tools," Proceedings of the ASME 2007 International design Engineering Technical Conferences & Computers and Information in Engineering Conference, Sept. 4-7, 2007 (DETC 2007-35699) (ASME 2007) ("Griffith" or the "Griffith article").

I have reviewed the most recent Office Action by the Patent Office sent to me by patent counsel. In pertinent part, the patent was rejected on the following grounds in the Office Action of July 5, 2007:

> "Claims 145 and 149 are rejected under 35 U.S.C. 103(a) as being unpatentable over Jeffery et al. in view of Smith (4,497,355). Jeffrey et al. discloses the invention substantially as claimed except for an included angle from the standard 65-70 degree. However, Smith teaches the use of an included angle of 65 degree for the purpose of assuring the effectiveness of the chisel and prolonging its life. I would have been obvious to one having ordinary skill in the art at the time the invention was made to have modified the device of Jeffery et al. by providing the included angle of 65 degree as taught by Smith in order to obtain a device that assures the effectiveness of the chisel and prolong its life."

Office Action of July 5, 2007 at p. 5.

I have also reviewed the Jeffery art (U.S. Patent 3,320,986 issued in 1967), over which the patent was claimed to be obvious.

First, the statement is made by the Patent Office that "Smith teaches the use of an included angle of 65 degree for the purpose of ... prolonging its life."

This is not a correct conclusion. Based on my years of experience working with testing, and from practical observation, the sharper the angle of the chisel, the shorter the life of the chisel. A less acute angle enables the impact of the edge upon the object being cut, here a metal edge applied to cut a drill rod, to be more evenly distributed on the end of the chisel. If the angle is made sharper, more pressure is concentrated in a smaller area, and the edge of the chisel breaks down faster.

The Smith art, by its terms, has only application to wood chisels: "The present invention relates to wood cutting devices and implements and more particularly to wood chisels, plane iron blades, and the like wherein the blade portion of these devices is provided with grinding guides for enabling the cutting edge to be properly sharpened." Smith, U.S. Pat. 4,497,355, col. 1, lines 6-10. As a sophisticated practitioner in tool testing and design testing (not merely one of ordinary skill), and having viewed and tested many tools, I read that Smith art to call for "the blade portion of such device …[to be] provided with grinding guides which an individual may use to assure that the cutting edge is sharpened squarely and that the angle of the beveled surface is properly angled. Smith '355 at col. 1, 55-61. Merely looking at the Smith art and the Jeffrey art together would not lead to the combination this inventor suggested because as I have shown in testing and as set in the Griffith article, most polymer materials would not survive the repeated hand chisel blows with or without having a more acute point to the chisel. Secondly, because the dynamics and stresses of a metal cutting chisel or orders of magnitude greater than those of a wood chisel, what is functional with a wood chisel, assuming the Smith patent had focused on the angle at all, is not suggestive of functionality with a metal-cutting chisel. Only certain materials and a properly selected chisel angle would yield the results of this invention, and then only after extensive testing. The obvious conclusion to me as a skilled practitioner in the art,

based on the Jeffrey art, is to find is to find some polymer material that will hold up under repeated hammering (Jeffrey suggested a non-polymeric material, copper as the preferred mode). However, that would not yield the claimed cutting effectiveness. Based on the Smith art, the obvious conclusion to me as a skilled practitioner in the art is that the Smith invention because of the angled lines in the Smith invention, would enable more rapid and accurate re-sharpening of the chisel. An experienced practitioner would know that making a more acute angle would not extend the chisel life, rather, the opposite would be true. In contrast to the Smith art, McCarty's objective in the present invention and the objective of the testing in the Griffith article was to eliminate the need for re-sharpening as much as possible, because the edge deterioration caused degraded chisel performance and worker fatigue, and too much time is lost to re-sharpen the chisels.

Some background about hand tools and my interest in the area of tools is in order, I believe. I have been interested in improving the ergonomics for workers for some years in equipment that workers use. When I refer to ergonomics, I am referring to, and the industry meaning is, improvements that enhance productivity and safety. Those improvements in the hand tool area would be reduction in noise and physical vibration of the tool on impact which improve productivity, and reduction in tool hazards such as chipping, spalling or mushrooming of the tool head which results in chips, and again, vibration, but now meaning in the sense of noise and sound level.

There has been a persistent and long term problem with improving tool safety related to hand tools that are struck. Specifically, the problem relates to spalling and mushrooming of the end of a tool struck by a hammer, and the resultant danger from the sharp edge to personal safety from cuts, or danger from flying bits that ultimately peel off and are split away on impact. The

Jeffery art cited by the patent examiner (U.S. Patent 3,320,986) was an effort to answer this problem, but as my experience and Jeffrey's patent disclose, Jeffrey expected and contemplated flattening and mushrooming of the cap giving rise to the cap ultimately splintering.

Equally undesirable is to have a cap that, to put it in non-engineering terms, absorbs too much of the impact blow. A hand chisel could be designed and Jeffrey referenced a "soft" material so as to mushroom out when struck and form a dome shaped head." (Jeffrey '986, col. 1, lines 49-53). Such a soft material either fails on impact, or absorbs so much energy that the extra hits required to use the chisel induce worker fatigue, which hinders productivity and gives rise to dangers to worker's limbs and muscles from repetitive hits. This can lead to stiffness and aches and in extreme cases, to more lasting injury. The Jeffrey art as described, and any obvious improvement using his art, failed to accomplish the objectives that would improve ergonomics.

What the inventors here achieved in a completely non-obvious way was to take the opposite tack of what the examiner appears to be thinking.

The second premise that is important to grasp is that the maximum impact for cutting metal (we use ¼ inch drill rod for testing) is by having a material that will absorb the least amount of energy. Jeffery could not achieve this because the materials he suggested, and moreover, the materials available at the time, absorbed too much of the hammer blow on the head of the chisel and inadequate energy and consequent force is applied to the cutting rod so that many more blows are required for a Jeffery chisel with a polymer cap that without such a cap. This has negative ergonomic effects because a worker becomes tired and frustrated.

As I explain later, simply selecting a shaped polymeric material is not a solution. Many polymeric materials break down and do not survive even one cycle of an effort to cut a ¼ inch drill rod.

We select a ¼ inch drill rod because in the industry, this is a readily obtainable material of standard characteristics where repeatable results can be observed to determine characteristics of a particular hand chisel such as vibration, frequency of sound emanated, number of blows to cut, and is representative of the many applications of a hand chisel, especially a metal-cutting chisel.

The inventors, now seen in years of testing and in hindsight, determined that by using a material which was reinforced in a particular way, and combining that with a more acutely angled chisel, they would be able to maintain impact effectiveness as measured according to a particular standard.

In the office action, reference is made that the material is able to yield a greater proportion of the force of the blow to be transmitted to the chisel (" see col. 2, lines 9-15 [of the Jeffery art], where the material is able to yield a greater proportion of the force of the blow to be transmitted to the chisel)." Office Action of July5, 2007 at p. 3.

While the Jeffrey art may have represented to the patent office that the material would yield a greater proportion of the force of the blow to be transmitted to the chisel, based on my actual testing experience, there would not be a greater proportion of the force of the blow being transmitted compared to the force of a blow on the bare metal chisel.

More importantly, these inventors created a design and selected a material that was deliberately designed to be opposite what Jeffrey sought; these inventors sought to and did reduce the proportion of the force of the blow to be transmitted to the chisel.
By selecting just the right material to reduce the proportion of the force of the blow to be transmitted to the chisel, and combining that with increase in included angle to make the point of the chisel more acute, the McCarty et al inventors in the present invention achieved what neither

Smith nor Jeffrey achieved. What McCarty et al claim is the combination of material and included angle that enables "said shaped polymeric material being of sufficient cross-sectional area for transmitting impact upon the impact end area, of appropriate thickness through said cross-sectional area, and of sufficient modulus to enable greater than sixty-seven per cent impact effectiveness compared to a similar impact tool without said polymeric material disposed adjacent to said striking end. " See, for example the closing limitation of Claim 143.

The Griffith article at page 5 discussed the impact resistance of the present invention: "This application requires materials of very high impact resistance that withstand repeated blows of several thousand pounds each.... in this application, a high modulus is needed to develop a high force under the chisel." Griffith et al, page 5, column 1.

My testing shows that a cap such as Jeffrey designed would not be capable of falling within the claims such as Claim 143 which reads:

"143. An impact tool comprising:

a shaft having a striking end and a working end; and

a shaped polymeric material, reinforced by a material selected from the group of fiber or mineral, to be impacted disposed adjacent to said striking end to avoid direct metal-to-metal contact,

said shaped polymeric material having a striking end area of said polymeric material adjacent to said striking end and an impact end area to be impacted roughly opposite said striking end area,

said shaped polymeric material being of sufficient cross-sectional area for transmitting impact upon the impact end area, of appropriate thickness through said cross-sectional area, and of sufficient modulus to enable greater than sixty-seven per cent impact effectiveness compared to a similar impact tool without said polymeric material disposed adjacent to said striking end."

A general polymeric material referred to in Jeffrey, absent a more acute chisel point would either break (as in the tool I tested, discussed later) or simply take considerably more

blows, such as 15-20 blows to cut a standard drill rod. With a more acute chisel point, selecting the hardest polymer materials, and particularly the hardest reinforced polymer materials, would result in a breakdown of the chisel point. Thus, in my expert opinion, as the chisel was used repeatedly, the edge would quickly be duller and duller resulting in the necessity of the loss of time to re-grind the chisel point, but only after the ergonomic fatigue for a worker had occurred.

The difficulty of achieving the claims in the invention, based on the invention disclosure, are illustrated by a recent effort to compete with the invention. Recently, a competitor entered the market, and I tested the chisel which attempted to imitate the invention and the hand chisel presently marketed by Hard Hat which embodies the technology.

On or about January 13, 2009, I conducted tests on a competitive tool to the Invention. which was sent to me for testing by Hard Cap Technologies, LLC and its owner H. Downman McCarty, II. I had independently procured a set of the tools at my cost from Northern Tool Co. bearing the trademark GRIP. The product description which can be seen on the Northern Tool Co. website is "Grip Heavy-Duty Punch and Chisels — 4-Pc. Set, Model# 61126." Northern Tool is located at 2800 Southcross Drive West, Burnsville, Minnesota 55306.

These "Grip" tools, comprising a hand chisel with appear to be polymer materials which at least facially should achieve the characteristics of the Hard Cap chisel.

The testing which I had previously done on the invention involved hundreds of impacts on an automatic hammer and testing machine. This machine enables repetition of precisely the same blow with the same energy.

I would describe the GRIP™ hand chisel as follows:

- The chisel top is rough finished and not flat – it appears to be a regular unmodified cold chisel.
- The cap contains sharp corners (i.e. no fillets) inside where the side walls meet the top.

- The cap contains several void areas, particularly along the thicker portions of the fracture surface. This indicates a lack of consideration of the molding characteristics of polymer.
- The cap material will melt indicating that it is a thermoplastic material.
- The cap is made of a polymer material based on the fact it will melt at low temperature, but the specific family is unknown.
- The chisel uses a 70 degree angle.

First, I had been told by Hard Cap that it had attempted to test the GRIP polymeric cap hand chisel cutting ¼ inch drill rod placed on a floor. It had failed almost immediately.

The test which I had normally applied to a Hard Cap chisel was to use it to cut what is often referred to as ¼ inch drill rod on an anvil, that is: steel rod of suitable hardness to be used for drill bits. This is a typical testing material for hand chisels.

Independently, I conducted a test to cut ¼ inch drill rod. The GRIP polymeric cap hand chisel failed after two hits while manually cutting a 0.25" rod on an anvil. Based on this, I ran a second GRIP polymeric cap hand chisel in the hammer testing machine striking the cap dead center, and it failed after three hits.

Thus, when a competitor simply applied the Jeffrey art, the cap failed and I was unable to compare even one cycle of durability of the GRIP tool.

Based on my experience, I believe the description by Jeffrey in his art as to how his polymer capped hand chisel functions is correct. Jeffrey contemplates deformation ("said head being formed of a soft material so as to mushroom out when struck and form a dome-shaped head.") (Jeffrey col. 1, lines 49-53); ("it will be observed that after the head 24 has been struck a certain number of blows it will have flattened and mushroomed to form the partly domed shape of head indicated at 27.") Jeffrey col. 3, line 27-col. 4 line 3). Thus, Jeffrey '986 teaches deformation, and teaches away from the conception of the present invention. The problem with mushrooming is a safety problem because mushrooming causes splintering of the cap and

splinters can fly off when the cap is struck after mushrooming has occurred. The desired mushrooming in Jeffery '986 contemplates a taffy-like material that will deform to a desired shape; this is precisely the opposite of the present invention. Further, there is no end to the deformation of the Jeffery invention under repeated blows. The ultimate effect of the Jeffrey cap failure is that the sound attenuation and frequency shifting characteristics of the Jeffrey cap do not persist as they do in the present McCarty invention, and the highly undesirable and hearing-damaging high-frequency "ping" of metal to metal contact occurs.

Further, returning to Jeffery's description of his '986 invention concerning deformation: ("said head being formed of a soft material so as to mushroom out when struck and form a dome-shaped head.") (Jeffrey col.1, lines 49-53); ("it will be observed that after the head 24 has been struck a certain number of blows it will have flattened and mushroomed to form the partly domed shape of head indicated at 27 Jeffrey col. 3, line 27-col. 4 line 3, "), the only way for this to occur in my expert opinion is to absorb a sufficient amount of energy to flatten the cap such that less than 67% impact effectiveness is observed, meaning it takes too many hits to cut a standard rod, and thereafter, the metal to metal contact and the undesirable noise and physical vibration characteristics emerge. Deformation must absorb energy. Having tested many polymer materials , absent those specified in this invention and only then in combination with a more acute chisel angle can any polymer capped tool that will survive repeated impacts achieve 67% impact effectiveness.

Thus for the materials referenced in Jeffrey, they either cannot withstand the repeated blows for use on a hand chisel, or if they can, they cannot maintain the greater than sixty-seven percent impact effectiveness. In the case of the GRIP chisel, this occurred after three hits. In the

case of many other cap materials we tested, they failed or simply did not measure up to the McCarty invention.

The polymer cap, even in the present invention, will always reduce the force of the blow transmitted to the working end of the chisel.

Also, in my experience and as would be well-known, and therefore undesirable, making the chisel angle more acute always shortens the life of the chisel. Shortening the tool life would not be the ordinary direction to take any design.

What the McCarty invention only claims is a particular combination of materials yielding a specific range of results by the addition of a cap relative to a bare chisel which chisel has been modified to a more acute edge which acute edge only works and survives repeated use because of the combination with a reinforced polymer cap which absorbs some of the impact shock but not too much.

In my opinion as a skilled practitioner, and not merely one of ordinary skill, Jeffrey's description does not teach using a hard reinforced cap capable of withstanding repeated high impact hits; Jeffrey teaches a soft cap that deforms. In technical terms, Jeffrey taught and suggested a low modulus material; these inventors went the opposite direction but only did so in combination with a more acute chisel angle.

Smith, U.S. Patent 4.497,355, makes no reference to using an included angle of 65 degrees to prolong the life of the chisel. My testing shows that the 65 degree angle shortens the chisel life. Smith proposed grid lines to enable achievement of a consistent angle of sharpening, whether 65 degrees or any other measure because such grid lines would increase the accuracy of sharpening and facilitate fewer unnecessary re-sharpenings. More accurate re-sharpenings would limit errors and reduce the necessity of correcting a particular action of sharpening and the

chisel should last longer. Smith does say, as he could not, that the more acute angle prolonged the chisel life.

These inventors, McCarty et al, headed in a different direction form Smith, and particularly for a cold chisel which is entirely unlike the Smith chisel, recognized that by combining a high impact resistant, shaped reinforced polymer head with a more acute angel, they could for certain classes of polymers, realize high cutting effectiveness.

As referenced in the Griffith article at p. 6, "a number of simple hammer impact tests were conducted on a range of thermoplastics, including elastomers (Hytrel™ family), polyacetal (Delrin™), carbon fiber reinforced materials, polyesters, and nylons. Most materials failed readily after only a few blows."

See Griffith article at 6-7.

Jeffrey's cap and invention suffers from the further economic and ergonomic disadvantage that it must be "broken in" as described by Jeffrey in order to deform the cap. The McCarty invention is ready-to-use and needs no worker use or modification to be used. Moreover, once a thermoplastic begins to deform, it will continue to do so in a cap formulation and disintegrate as the experiments with the GRIP tool show. The worker is left hitting bare metal and suffers the increased physical vibration to the hand, and vibration as a high pitched and dangerous noise, and the risk of spalling and chipping. Jeffrey referenced nylon, but when ordinary nylon was tested, it failed in our University of Delaware tests referenced in the Griffith article.

The combination leading to the claim achieves objectives of the inventor, and objectives that I was interested in as a person in the academic community: namely high durability,

redistributed sound, and substantially decreased vibration without substantially increasing the time for cutting or the ergonomic burden on the user.

As a matter of academic interest, my team at the University of Delaware tested a variety of materials. Our university works with DuPont Corporation, which is based here in Delaware. As described in the Griffith article, after McCarty et al had proposed the invention, and a material, we tested many materials. "a number of simple hammer impact tests were conducted on a range of thermoplastics, including elastomers (Hytrel™ family), polyacetal (Delrin™), carbon fiber reinforced materials, polyesters, and nylons. Most materials failed readily after only a few blows."

See Griffith article at 6-7.

The invention, the Hard Cap hand chisel which is the subject of pending patent application 10/625,149 on which I commenced testing is an example of why the proposed invention is not obvious, and in fact has surprising characteristics. It is those surprising characteristics which candidly, have enabled me to enhance my stature in my field because the tool presents unique opportunities for testing because of its surprising and unusual characteristics as developed by the inventors.

Based on this effort by a commercial competitor to create the invention by Hard Cap and Mr. McCarty et al, and based on my experience and expertise, and looking at the present commercially available products, I came to several conclusions.

First, it has taken years of analysis and testing to select a material that conforms to the characteristics set out in the claims to the invention, and in fact, during my testing of the invention, the material first selected turned out not to be optimal.

Second, the difficulty to be overcome is to balance a selection of "softness" to reduce sound and vibration with the necessity to avoid the undesirable characteristic of a poor characteristic of cutting. That is what the cutting effectiveness test in the claims to the invention accomplishes. Only a limited and not at all obvious set of materials will meet that test, and achieve the other ergonomic characteristics of the Hard Cap hand chisel with the particular polymeric cap. When I refer to "softness," I refer to a characteristic that reduces sound and vibration, but always results, until this invention, in the necessity of many more hammer hits. For a worker using the hand tool, this extra repetition of effort costs time and is ergonomically undesirable because more strokes would be required and fatigue sets in. The inventors had the insight to combine several aspects in their invention including making the chisel angle more acute to increase the cutting ability, recognizing that the invention could be manageable with the more acute cutting angle because the force transmitted through the cap would be slightly reduced. Further, they discovered a particular material, namely a reinforced nylon that would reduce vibration and fatigue, yet maintain cutting effectiveness. I tested multiple chisels with the Hard Hat cap hundreds of times to test the characteristics and published a peer-reviewed paper which is attached. In order to determine a material to conform to the claims of the invention without the disclosure of the invention would require extensive experimentation. This challenge was overcome by McCarty et al in their invention without extensive experimentation although experimentation confirmed their invention. Even after their selection of a material, they requested extensive testing and undertook re-selection of the material.

Candidly, the McCarty invention is one of the few advances in ergonomic chisel design to have occurred in at least the last 40 years assuming Jeffery was novel in its time (1967) to have a cap deforming to the chisel head.

What would appear to be an obvious conclusion from the Jefferson patent in fact turns out to incapable of being compared with the invention because it does not have even the necessary durability to sustain multiple hits in our standard tool-testing hammer machine. The Grip-Rite competitive tool which is made of a polymer falls outside the cutting effectiveness test which is in the claims of the patent application. Even if the competitive tool had flattened and rounded its corners, and improved its molding quality, it would not, in my opinion, survive the hundreds of impacts the inventor's chisel has withstood in our standard tool-testing hammer machine. In fact, examination of the Grip-Rite competitive tool cap material revealed no reinforcing constituents were present in the polymer. This was determined using the ASTM D2584 *Standard Test Method for Ignition Loss of Cured Reinforced Resins*, in which pieces of the cap were incinerated at 1050 degrees Fahrenheit for one hour, and the mass of remaining constituents were measured. In this case, there were no remaining constituents indicating the polymer used by the competitor was not reinforced, and therefore was substantially weaker and less stiff than the polymer used in the invention.

One would have thought that using a fiber or mineral reinforced material would make sense even though those materials did not exist as of the time of the Jeffery art, but the manufacturer of the GRIP chisels apparently did not believe this. The materials are very expensive, and many of them fail, and without the combination of testing, the correct material choices as selected by the inventors and the combination with a more acute chisel point, the extremely positive results obtained by this McCarty invention simply don't occur.

One could argue that using engineered reinforced polymers which emerged in the early 1970's, after the Jeffery invention, would be useful. My experience learned from testing the invention, as I stated earlier and as referred to in the Griffith article, is that only certain polymers,

even among the class of reinforced polymers, and then only after testing, will meet the cutting effectiveness criterion of the claims in the invention. McCarty conceptualized and overcame the obstacle that most polymers fail by selecting the certain correct materials and combining them with a different design of the chisel point and produced a product which was a significant advance.

I should also add that to prove out this concept, there was yet another invention, and that was the design of a new testing device for hand-struck tools. Absent that new testing device, there was no known consistent way to conduct the experimentation to determine the viability of the present invention. Thus, the present invention only occurred after extensive verification, and a recently introduced competitor with a polymer cap simply failed.

Currently, no standard test methods exist to assess the performance characteristics of hand-struck tools . This makes evaluations and comparisons very difficult since performance characteristics are significantly influenced by the user of the tool. As a result, for the purposes of developing and assessing the novel performance characteristics of the invention and to prove out the design, a new testing device for hand-struck tools had to be and was developed. The device is designed to simulate the approximate cyclic kinematic motion of a user repeatedly hitting a tool with a conventional hammer. A computer controller automates the striking and return stroke actions, and the resulting impact velocity and force exerted by the hammer are adjustable. The resulting impact velocity and force exerted by the hammer approximate the performance of a human. For the purpose of development, the testing device was designed to accept steel hand-struck chisels. As configured, a chisel is placed in the device and used to shear a standard, replaceable work piece. The key output of this test is the number of impacts needed to fail the standard piece. The device can also be used for longer term tests to assess durability. Other

features integrated into the device include a load cell under the work piece to capture the force exerted during a hammer impact, measurement of the hammer velocity at impact, noise measurements, and an automatic counter to record the number of hammer impacts required to fail the work piece. The work pieced used was a standard test on a ¼ in. drill rod. As described in the article I co-authored and supervised, we also were able to measure vibration. Griffith M. et al, "Polymer Composite-Based Vibration and Noise Emission Controls for Hand-Struck Impact Tools," Proceedings of the ASME 2007 International design Engineering Technical Conferences & Computers and Information in Engineering Conference, Sept. 4-7, 2007 (DETC 2007-35699) (ASME 2007).

Based on my experience with tools, and other tools we tested, no tool maintained the impact effectiveness and had the force exertion and ergonomic advantages of noise reduction and safety from the combination of material, cap design and included angle modification of the McCarty et al invention.

In sum, the suggestion that the disclosure and claims of McCarty are obvious is not consistent with my experience, with the art cited, nor the market and products available in the market. It is not suggested or obvious in light of the Jeffery or Smith art.

I hereby declare that all statements herein of my own knowledge are true and that all statement made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Section 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Date: 27 March 2009

Signature ______________________

James L. Glancey

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POLYMER COMPOSITE-BASED VIBRATION AND NOISE EMISSION CONTROLS FOR HAND-STRUCK IMPACT TOOLS

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ABSTRACT

Exposure to high noise levels may be the most common occupational hazard. Recent estimates suggest that as many as 30 million Americans are exposed to noise levels greater than the current safe limits for workplaces. At current durations of exposure, it is expected that 25% of these workers will develop permanent, noise-induced hearing loss. In many of these industrial environments, high levels of vibration also exist that can lead to several injuries and ailments. To address the adverse effects associated with the use of high noise emission impact tools, a study was initiated to develop and evaluate alternate tool designs that reduce the potential for hearing loss and vibration-related injuries. Recent work has focused on integrating advanced engineering polymers (composites) into tool designs for the purpose of eliminating direct metal-to-metal impact. This approach has several significant performance advantages including reduced operator discomfort due to hand-arm mechanical shock, reduced noise, and less danger from flying metal fragments. To quantify sound emission characteristics of these new designs, continuous sound pressure, maximum sound pressure, and maximum sound pressure level were measured using an array of five precision microphones each located 1 meter from the tool. Data was sampled at 40 kHz while test subjects operate both pneumatic tools and hand-struck tools. Frequency spectra of the sound pressure signals were examined for all tool treatments, and indicate that the addition of a polymer insert between metal impact components significantly reduces noise emission, especially at higher frequencies. Similar reductions were observed in vibration transmission in the hand and arm. As a result, tools that integrate polymer-based components may be operated for longer daily exposure times without inducing hearing loss or vibration-related injuries. Data from this study may also help auditory and ergonomic specialists in understanding impulse noise characteristics and exposure.

KEYWORDS

Hand-struck tools, engineering polymer, impact, finite element model, vibration.

INTRODUCTION

The use of hand-struck tools is an integral part of many industries throughout the world. In fact, many jobs require frequent and often continuous use of these devices. Injuries in the workplace resulting from these tools have been studied extensively, and have been classified as single-incident or cumulative trauma. (1) Single-incident occurrences are often attributable to a one time misuse or overexertion. The factors that contribute to this type of trauma include the tool type and design, the workplace environment, and the skill and fatigue of the operator.

The causes and resulting effects associated with cumulative trauma are much more complex than single incident circumstances. Several studies have demonstrated a link between exposure to the vibration from tools and various injuries including vibration induced white finger, hearing loss, and Hand Arm Vibration Syndrome (HAV). (2, 3, 4, 5, 6) These ailments have been estimated to be prevalent in several industries, and pose a growing concern to the long term health of workers worldwide. In a study of more than 400 chain saw operators, symptoms of HAV were found in 11.7% of workers with 20 to 24 years of exposure, and 20.9% of works with more than 30 years of exposure. (7) An evaluation of 52 studies across several different industries with occupations that included hand and arm vibration exposure found that 43 studies reported worker incidence rates of injury of more than 20%. (8) In the United Kingdom, more than 1.2 million men and 44,000 women were determined to be exposed to daily levels of vibration that exceeded the suggested daily levels. (9) The resulting economic consequences of vibration-related injury have been estimated to be substantial. In 1986, the cumulative costs of hand tool injuries were approximated at $10 billion annually. (10)

In light of the problems associated with the use of hand tools, a study was initiated to evaluate the performance of conventional hand-struck tools and develop improved designs that can mitigate some of the detrimental effects associated with their long-term use. The initial focus of the work was on improving cold chisel designs used for cutting metal.

LITERATURE REVIEW OF HAND TOOL RESEARCH

The design of hand struck tools and the materials and methods used to manufacture them have evolved very little historically. Most tools are still manufactured from medium to high carbon steel, and the basic configurations of typical hand struck tools including chisels and punches have remain unchanged for centuries. Most work in recent decades has focused on improved designs for power tools, and is driven by their larger market presence and value compared to hand struck tools. Power tool research is diverse and includes quantifying the magnitude of vibration emanated from common tools, determining the factors that influence the transmission of vibration energy to the user, and improved designs and devices that reduce the vibration and forces exerted on the hand and arm. This work has resulted in power tool designs that reduce the vibration energy transmitted to the user (11), as well as several innovations including anti-vibration gloves (12), air-bladder technology (13), and vibration attenuating handles. (14)

Other studies that have possible relevance to hand-struck tool improvements have modeled and tested hand-arm-tool systems. Kihlberg (15) found that exposures with frequencies less than 50 Hz caused a greater load on the elbow and shoulder while exposures above 100 Hz, typical of impact tools, induced greater loads on the hand and fingers. Other studies have also shown that more energy is transferred to the hand under impact (16, 17), and models have predicted that the higher frequency energy induces higher stresses in the fingers and ultimately dissipates in the hand palmar tissues and may be one cause for the incidence of vibration-induced whiter finger. (18, 19)

OBJECTIVES OF THIS STUDY

The overall goal of this work is to improve conventional hand-struck tool designs in order to reduce the detrimental effects associated with there long term use. Furthermore, our intent is to achieve these improvements without sacrificing tool performance and utility. For the purposes of this study, the focus is on hand-struck tools with an emphasis on steel chisels used for cutting metal. The specific objectives are to model the hammer-tool system, and evaluate through modeling and testing possible improvements. Possible improvements to be examined include the integration of non-traditional materials like advance engineering polymers into chisel designs.

Modeling and Analysis of the Force Transmission Characteristics of a Chisel with a Polymer Cap

To understand the behavior of a hammer-chisel system during impact as well as the design requirements of the cap illustrated in Figure 1, a simple lumped-mass model to predict the force the chisel imposes on the work was developed. This force depends on a number of system components including: hammer weight and velocity; chisel parameters; and polymer cap parameters. A relatively simple lumped-parameter model was used. In spite of its simplicity, this model permits inclusion of all the pertinent inputs and outputs.

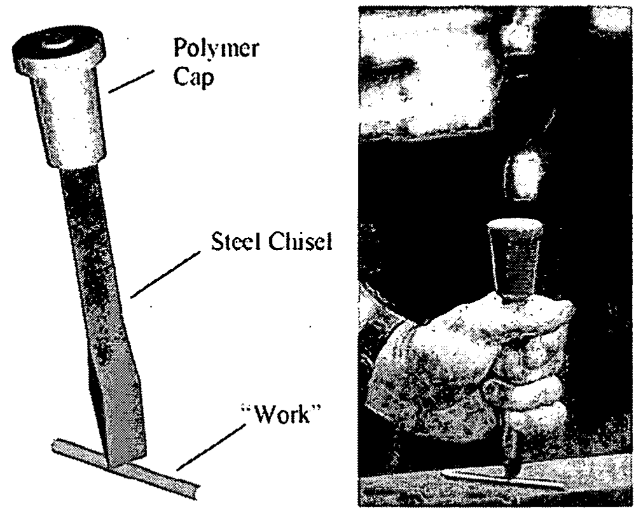

Figure 1. Conceptual view and prototype of a conventional steel chisel fitted with a reinforced polymer cap.

Force Transmission Model Description. A lumped-parameter model was used, and consisted of four simple elements, two masses and two springs. These idealized computational elements simulate the actual components. In all cases, only forces and displacements in the axial direction are included.

For the model shown in Figure 2, Mass 1 is an element that simulates the hammer. At time=0, the hammer, moving at V, just impacts the top of the chisel cap. Spring 1 is an element

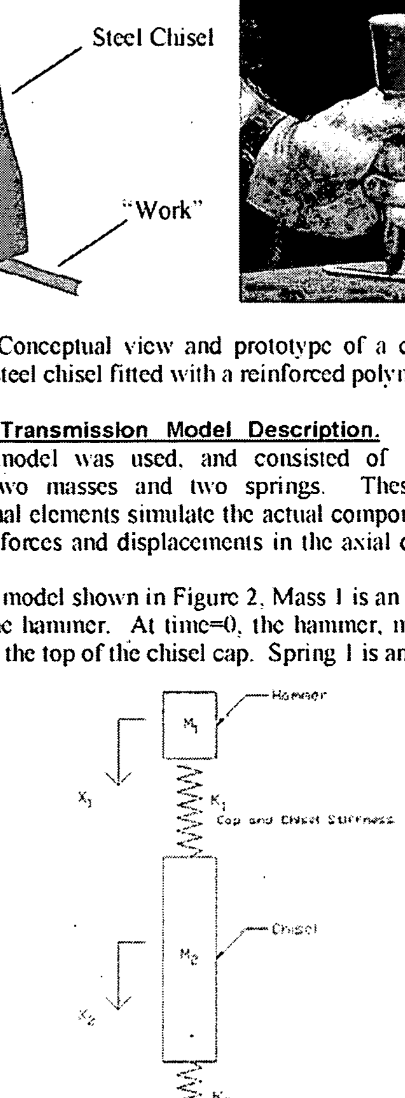

Figure 2. Spring mass model of the hammer-chisel system that includes a chisel cap.

that simulates deformation of the cap and the chisel itself. Its spring constant is that of a series combination of the cap and chisel. Mass 2 is an element that simulates the chisel. Note that this mass is important because it's inertia causes the force below the chisel to be different from that on top. Usually, the force under the chisel is lower than that on top. Spring 2 is an element that simulates the deformation of two things: the chisel

into the work and the deflection of the support under the work. In actual usage, the support under the work is very rigid. However, in experiments with a force gauge under the work, that stiffness needs to be included. The spring constant of this element is a series combination of both effects.

Using the model illustrated in Figure 2, a relatively simple analysis was made using the following basic differential equations with the indicated boundary conditions,

$$\ddot{x}_1 + \frac{k_1}{m_2}x_1 + \frac{k_2}{m_2}x_2 = 0 \qquad (1)$$

$$\ddot{x}_2 \;\; \frac{k_1}{m_2}x_1 \;\; \left(\frac{k_1+k_2}{m_2}\right)x_2 = 0 \qquad (2)$$

$$x_1(0) = x_2(0) = \dot{x}_2(0) = 0$$
$$\dot{x}(0) = V \qquad (3)$$

Simulations. The equations were solved using Matlab™ Software. To do this, the differential equations were rewritten in vector form in term of a four-component vector.

Most input parameters were determined by direct measurements. Only one parameter was adjusted – the effective spring constant of the chisel penetrating the work. This parameter was adjusted from measured chisel force to a value of 70.1 MN/m (.4 M lb/in). The complete set base case parameters is:

- Effective Hammer Weight = 9.21 N (2.08 lb) [computed from hammer and instrument arm weight].
- Chisel Weight = 2.69 N (.605 lb)
- Polymer Cap Diameter = 12.7 mm (.5 in)
- Chisel Effective Diameter = 16.8 mm (.661 in)
- Polymer Cap Thickness = 5.08 mm (.2 in)
- Chisel Length = 102 mm (4 in)
- Polymer Modulus = 1.90 GPa (.275 Mpsi)
- Steel Modulus = 207 Gpa (30 Mpsi)
- k2a = Cutting spring constant = 70.1 MN/m (.4 M lb/in)
- k2b=Base spring constant = 105 MN/m (.6 M lb/in)
- Hammer Velocity (ft/sec) = 5.64 m/sec (18.5 ft/sec)

A number of relations were computed with these values as well as a number or excursions. The next sections describe these computed results.

Chisel Force During an Impact. Force vs. time is plotted on Figure 3 for a bare, uncapped chisel and on Figure 4 for a polymer capped chisel. In each case, the forces are shown on top and bottom of the chisel. The force on the bottom is designated as the chisel force since it acts on the material being cut. The force on top does not equal that on the bottom because of the chisel inertia.

These graphs show that there are two dominant frequencies for the chisel force. For both bare and capped, the two wavelengths are approximately .3 and 1.2 msec. The maximum chisel force is only somewhat higher in the bare chisel; and, in the bare chisel, the force on top is significantly higher than that on the bottom.

Effect of Polymer Modulus on Maximum Force. An important factor in designing a capped chisel is to determine the effect of polymer properties on performance. Since we assume that maximum chisel force is the key variable affecting performance, we computed the relation between this variable and polymer modulus and the results are plotted on Fig 5. The experimental data plotted will be discussed in a later section. Maximum force is plotted against the polymer modulus divided by that of steel. A log scale is used to include the range of available polymers.

As expected, this computation shows that increasing polymer modulus increases the maximum chisel force. The reason for this effect is apparently the shorter, sharper impact with high modulus materials. The slope of the force-modulus relation is high for low modulus materials and relatively low for high modulus ones.

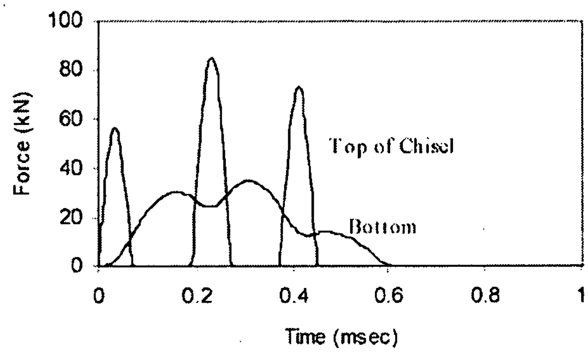

Figure 3. Computed force vs. time for a bare chisel.

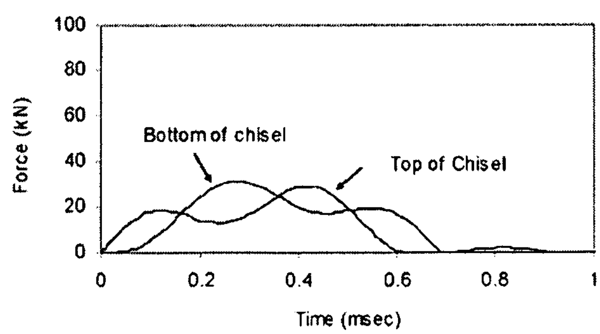

Figure 4. Computed force vs. time for a capped chisel.

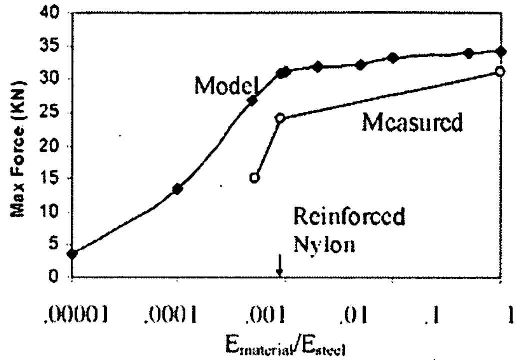

Figure 5. Effect of cap modulus on the maximum chisel force.

Note that this functional relation is not as smooth as might be expected. This occurs because of the oscillating nature of the force-time relation. In some cases the maximum force develops in the first cycle and sometimes on a later cycle. When the cycle that has the maximum force changes, the Fmax vs. E curve tends to be jagged. This effect occurs in most of the functional relations with system parameters.

Two important findings come from this relation. First, higher modulus polymers result in higher forces – as would certainly be expected. Second, high modulus polymer caps produce a maximum force relatively close to that of a bare chisel. This second finding is of great importance for the cap design.

Effect of Cap Thickness. The effect of cap thickness was computed and plotted on Fig 6 in terms of maximum chisel force vs cap thickness. The zero thickness level corresponds to a bare chisel. The experimental data on this plot will be discussed in a later section.

This relation is similar to the modulus effect on Fig 4 in that increased compliance reduces maximum chisel force. Compliance increases with thickness and decreases with modulus.

As explained in the previous section, this relation is jagged because the maximum force occurs at different cycles.

An important result of this computation is that chisel force does not fall sharply with increasing thickness. This is important in the development of a useable cap since relatively thick caps (>= 5 mm) are needed to avoid polymer failure.

Effect of Hammer Weight and Impact Velocity. Increasing either the hammer weight or impact velocity certainly increases chisel force. The model was used to compute the extent of this effect for a capped chisel and the results are plotted on Figure 7. As in the other plots, the base case parameters are used – except for the designated variations.

This result shows that the relation between force and impact velocity is essentially linear. Although the kinetic energy of hammer increases with the square of the velocity, the maximum force increases only with the first power.

Increasing hammer weight increases maximum chisel force. The rate of increase is significantly less than linear.

Effect of Other System Parameters. This model can be used to determine the effect a number of other parameters describing the materials or chiseling operation but for the sake of brevity, additional plots are not included. Parameters related to the compliance under the chisel can be quite important. Stiff supports under the work can increase force significantly – an effect well know by mechanics.

Another important effect occurs when the chisel cuts into the work. During this process, the compliance under the chisel increases as it becomes progressively harder to increase the amount of cut material. This increase in compliance under the chisel increases the force as was indeed observed by force measurements, but not computed because the cutting compliance change was not known.

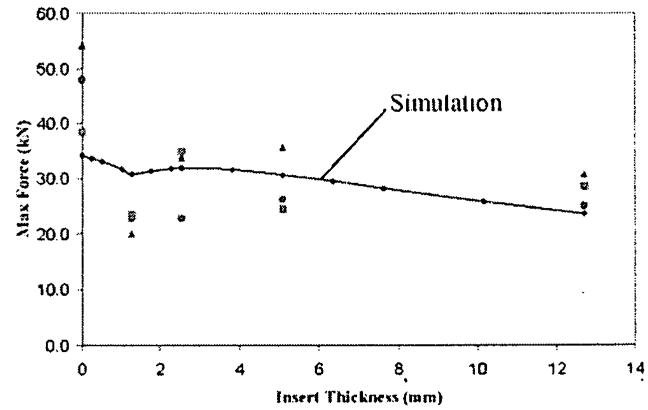

Figure 6. Predicted and measured maximum force exerted on the work piece during a hammer impact vs. cap thickness. Measured values are an average of 3 replicates.

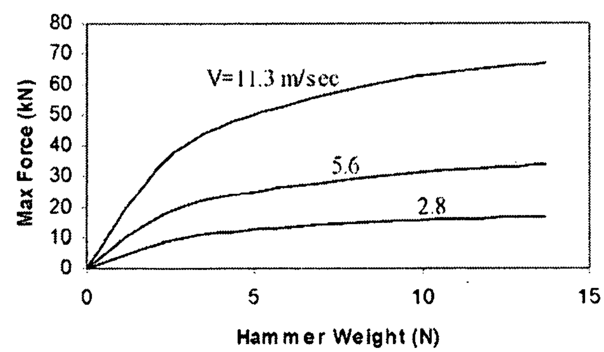

Figure 7. Predicted effect of hammer weight and velocity on maximum chisel force exerted by a capped chisel.

Cap Material Selection

We found that selecting the correct polymer is a critical part of developing a new capped chisel. Three factors are critical: performance, durability, and cost. Each of these is described briefly in the following sections.

Modulus. The performance of a chisel depends on the force transmitted through the chisel to the work. This force and

its relation to the system parameters are described in detail in the modeling and experimental sections, and the key results are plotted in Figure 5. As shown, high polymer modulus is needed to achieve a high chisel force. When the modulus exceeds about 1/20th the level of steel, the effect is small, but when it drops below that level, chisel force drops sharply.

The modulus of polymers varies through a wide range, depending on chemical composition and processing methods. In addition, many polymers can be reinforced with higher modulus materials to create composites with enhanced properties. This is done with continuous fibers (advanced composites) and with short fibers and/or minerals (engineering polymers).

We focused our efforts on short fiber and mineral reinforced materials because they provide increased modulus and much lower cost than advanced composites. Also, they can readily be manufactured into shaped parts.

Impact Resistance. This application requires materials of very high impact resistance that withstand repeated blows of several thousand pounds each. Impact resistance is typically determined by measuring the amount of energy required to propagate a crack through a material. A standard test commonly used for this purpose is the Izod test. In this test a sample is notched (optionally) and then impacted by a swinging pendulum apparatus.

Impact resistance of polymers generally increases with break elongation. Brittle materials tend to have low elongation and low impact resistance while elastomeric materials, such as Hytrel™, have high elongation and high impact resistance. Since modulus generally varies inversely with elongation, low modulus materials usually have high impact resistance. Unfortunately, in this application, a high modulus is needed to develop a high force under the chisel. A compromise is needed between low modulus, high impact strength materials and ones with high modulus and low impact resistance. We focused on nylon polymers because of their well-established durability and high impact resistance.

Manufacturing. In low price items such as cold chisels, manufacturing costs become critical. They affect the material selection in two key ways: material costs and processing costs. Furthermore, in projects with limited business projections, resources are limited and only readily available materials can be considered.

Relative to processing, plastics divide into two categories: thermosetting and thermoplastic. When processing thermosetting resins into parts, a chemical reaction is needed to complete the cross-linking of polymer chains. This complicates the process in terms of materials storage (shelf life limitations) and requirements on process control. Thermoplastics, on the other hand, are available as pellets. They are simply melted and injected into molds of the appropriate shape.

Processing quotes were obtained from several vendors and thermoplastics were found to be significantly less costly than thermosets for this application. Thermoplastic disadvantages that were considered include relatively high mold cost (due to pressure requirements) and higher material costs.

Specific Material Selection. Using the above considerations and a number of preliminary tests, we selected the appropriate polymer material. We did not do an extensive evaluation of many materials, but rather, we assembled available information and made an engineering judgment to select the starting material. Also, we selected a manufacturing process that could readily accommodate alternate materials should they be needed.

Based on manufacturing costs, we selected the thermoplastic process route. The key factors which led to this decision were process simplicity and fast cycle time. A number of simple hammer impact tests were conducted on a range of thermoplastics, including: elastomers (Hytrel™ family), polyacetal (Delrin™), carbon fiber reinforced materials, polyesters, and nylons. Most materials failed readily after only a few blows. Nylon was considered as the primary candidate because of its demonstrated durability, high impact strength, and reasonable cost. Nylon's modulus is relatively low compared to other materials, but it can be increased substantially by adding reinforcing material.

DuPont manufactures a number of reinforced nylon polymers within the Minlon™ family of products. As with most polymers, the modulus and impact resistance vary inversely with each other. We selected an intermediate level of both properties.

Effect of Cap Thickness. Three sets of caps were fabricated at several different thicknesses and tested with a hammer test instrument (Figure 8), and the results are summarized in Figure 9. Generally, the measured values of peak force were consistent among the replicates, and

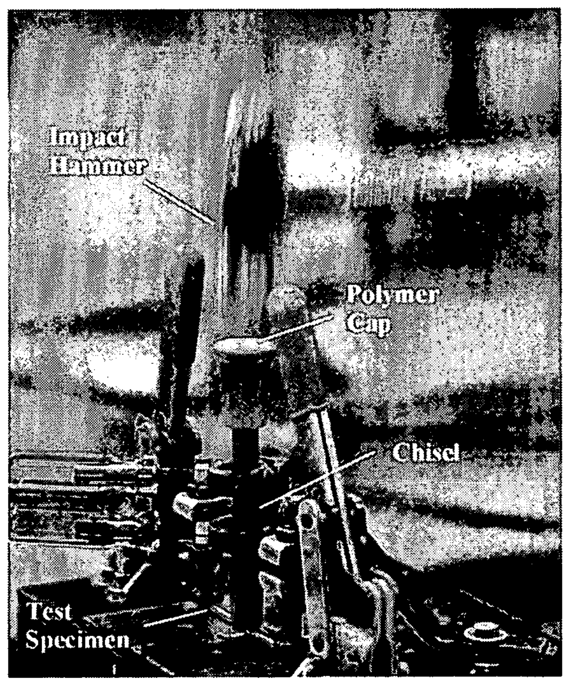

Figure 8. Chisel and cap installed in the test instrument used to evaluate various chisel and polymer cap configurations tested during this study.

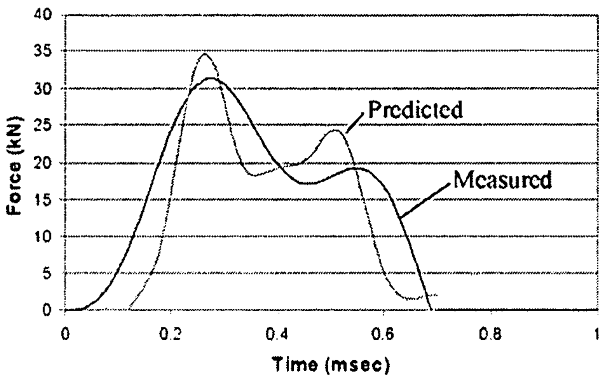

Figure 9. Measured and predicted force exerted on the test specimen by the chisel. Sampling rate = 100kHz.

very similar to the simulation results. As expected, the results show that increasing thickness reduces chisel force with a sharper drop for low thicknesses.

Effect of Chisel Tip Angle. Additional tests were conducted to assess the potential of reducing the chisel tip angle. Since the cap did reduce the peak force exerted on the chisel, sharpening the tip angle could be used to compensate for the change in force without sacrificing cutting efficiency or chisel life. Trials were conducted at chisel tip angles of 60° and 65° with both a bare chisel and a chisel with a 5.08 mm thick

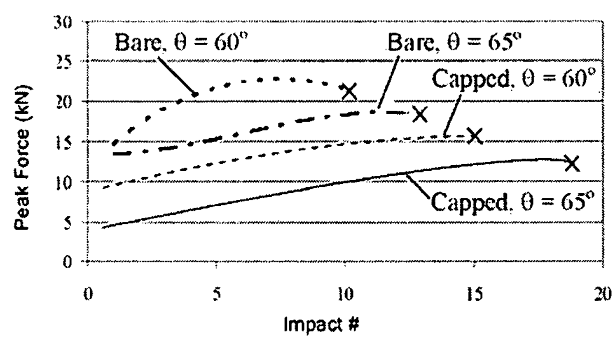

Figure 10. Peak force exerted by the chisel vs. chisel age for the capped and bare chisels at different chisel tip angles.

Minlon cap. Peak force for each impact during the cutting of a test specimen is plotted in Figure 10. The fact the sharper cutting angle resulted in higher peak forces was somewhat surprising and cannot be fully explained. One might expect the sharper tip to cut easier and therefore generate lower forces. Alternatively, the areas under the curves in Figure 9 could be viewed as a measure of energy input to the test specimen. Since the sharper tip cut the specimens with a fewer number of impacts, the energy per impact would need to be higher assuming the damage volume in the test specimen is about the same. Therefore, the peak force would be higher. More research is needed to fully understand this phenomenon.

Measurements of the number of impacts required to cut the standard specimen for different chisel configurations are summarized in Figures 11 and 12. These results indicate that a chisel with a combination of the Minlon cap and sharper chisel angle of 60° performs about the same as a conventional bare chisel with a standard 65° angle.

Durability Measurements. Using the cyclic testing device shown in Figure 8, long-term tests in which the capped chisel was hit repeatedly were used to assess the durability of the capped chisel. Results indicate a Minlon cap is capable of withstanding over 2000 dead-center impacts without failure.

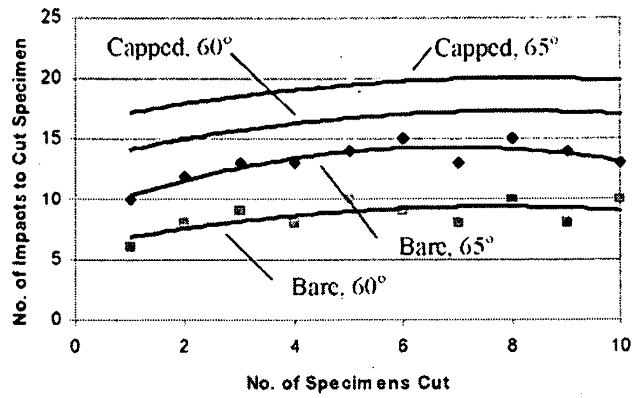

Figure 11. Number of impacts vs. chisel usage for various chisel configurations.

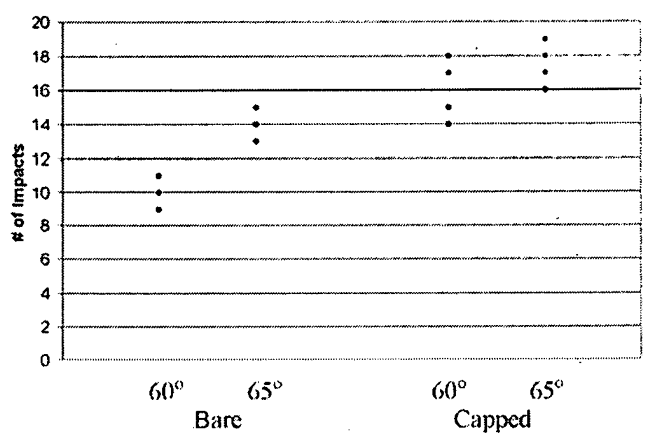

Figure 12. Measured number of impacts to cut the standard test specimen for various chisel configurations.

distortion, or wear. The effects of miss-hits and off-center hits are currently under investigation.

MEASSUREMENT OF VIBRATION AND SOUND EMISSIONS

Experimental Treatments.

To evaluate the potential effects of the polymer cap on vibration and noise emissions, prototype caps were injection molded and tested. Figure 13a and 13b show typical conventional and polymer capped metal cutting chisels, respectively, used in this study. In addition, a third chisel treatment was included in which a common urethane grip was placed around the shank of the chisel were the user grips the tool (Figure 13c).

(a) Bare Chisel (b) Polymer Capped Chisel (c) Polymer Capped w/ Urethane Grip

Figure 13. Chisel treatments evaluated in this study.

Instrumentation and Data Acquisition

Vibration measurements were made at the pneumatic chisel handle-hand interface using a PCB Piezotronics Tri-Axial Accelerometer (Model SEN021F) with a nominal sensitivity of 10 mV/g and a frequency response range of 1-10000 Hz. A small mounting fixture was used to position the accelerometer along the hand. Signal conditioning was performed with a PCB Piezotronitcs Model 480B21 Three-Channel Conditioner. A LinearX 150 mm diameter precision acoustic measurement microphone (Model M51A) with an acoustic sensitivity of 11.086 mV/94.00 dBspl was used for all tests. A DC supply of 9 volts powered the calibrated microphone and a National Instruments Data Acquisition Card (E-Series, PCMCIA 16-bit) and laptop computer were used to record the sound signal along with the vibration signals.

A *LabVIEW* program was written to interface to the A/D board and collect data as well as process, analyze and log the acquired signals (Figure 19). The averaged level of the sound pressure signal was computed based on an exponential mode after each sample of time and returned as an exponential averaged sound level in decibels. Selecting a custom exponential time constant of 125 milliseconds allowed for the continuous running average to accurately capture a short duration impulsive signal. Discrete Fourier transforms of the sound pressure and acceleration were performed using the following form:

$$F_n = \sum_{k=0}^{N-1} f(n) e^{i2\pi nk/N}$$

where,

F_n = Fourier transform

$f(n)$ = n^{th} measured time domain data

N = Number of data

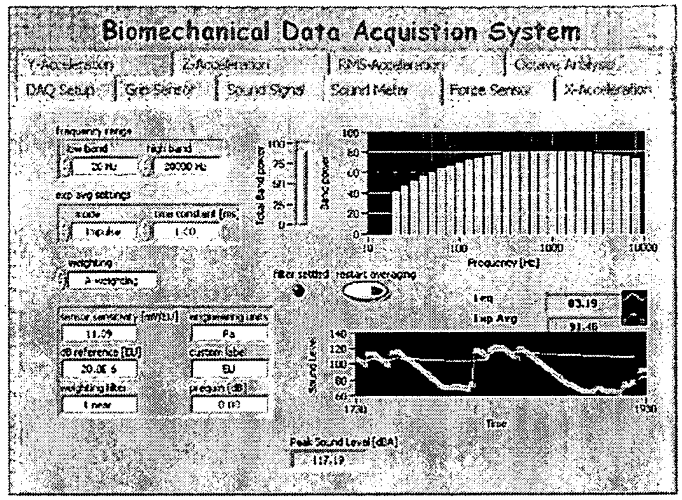

Figure 14. *LabVIEW* interface for the data acquisition and processing program used to collect and analyze the sound and vibration data.

Sound Measurements.

Tests were conducted to compare sound emissions from bare and capped chisels. On average, the peak sound pressure from a bare chisel was significantly higher than the capped chisel treatments. Figure 15 contains sound emission (pressure) vs. time for each treatment shown in Figure 13. The corresponding frequency spectra for each plot in Figure 15 is provided in Figure 16. The bare chisel produced distinct sounds between 4500 and 5000 Hz. In comparison, the capped chisel and capped chisel and urethane grip both significantly reduced the sound energy in this range.

Both the reduction in sound pressure across all sound frequencies and the suppression of certain sound frequencies achieved with the addition of the cap are significant. Human ears are particularly susceptible to hearing damage from noise at high frequencies, especially when exposed for extended periods of time. The beneficial effects of the polymer cap regarding noise suppression will substantially reduce the potential for hearing damage resulting from long term tool use and noise exposure.

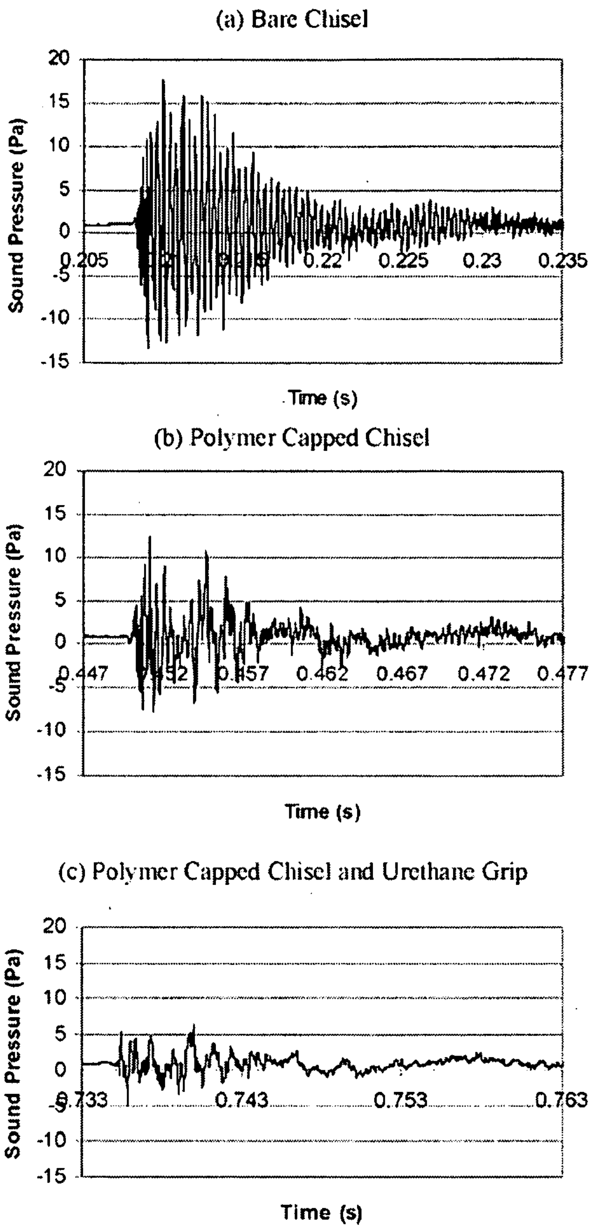

Figure 15. Typical sound pressure emission from a single impact with a (a) bare, (b) capped, and (c) capped chisel with protective grip.

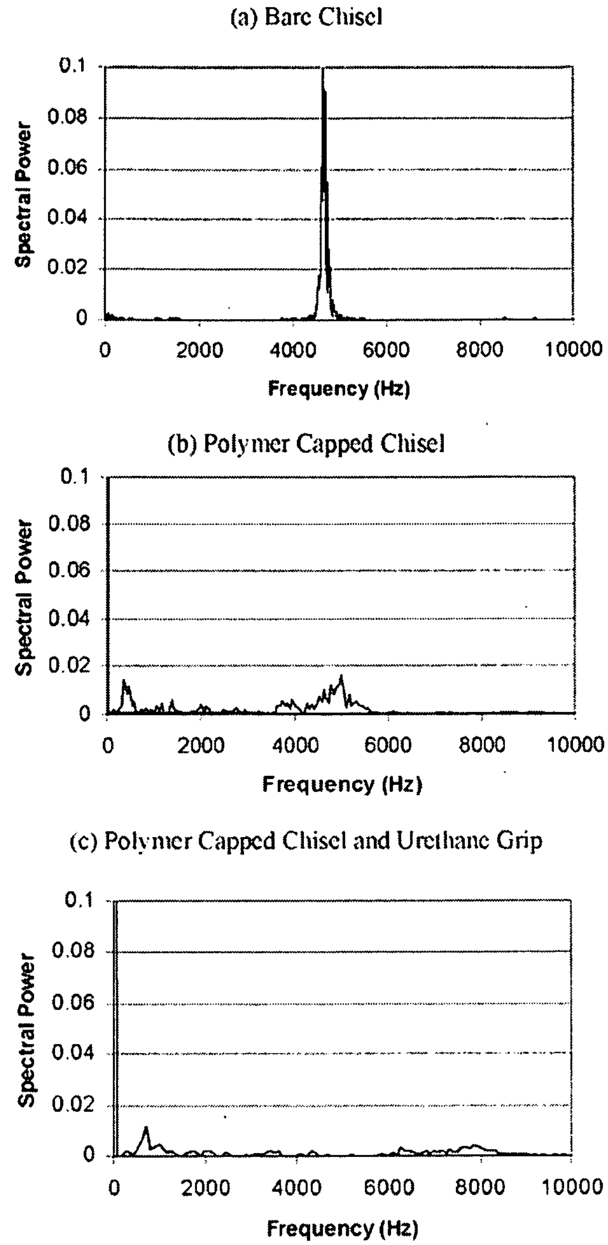

Figure 16. Typical frequency spectrums for a (a) bare, (b) capped, and (c) capped chisel with protective grip.

Vibration Measurements

Vibration measurements were made at three locations (palm, wrist, elbow), each with triaxial accelerometers. The vector sums were computed at each location. Three different users were tested using each chisel treatment, and ten replicates were recorded. Tests were performed in random order.

Table 1 contains peak acceleration values for each treatment. Values shown are an average of the ten replicates. The addition of a cap significantly reduced peak vibration levels compared to a bare chisel at the palm, wrist and elbow. The addition of the urethane grip did significantly reduced vibration at the elbow and wrist. Surprisingly, the addition of

the grip increased tool vibration at the palm. This is most likely the result of the added compliance provided by the grip, and the resulting larger displacements of the tool.

Typical acceleration vs. time plots at the wrist are provided in Figure 16, and illustrate the reductions in accelerations associated with the addition of the cap.

Table 1. Summary of average peak vector sum of x,yx vibration for each chisel treatment. Units are in g's.

	Bare Chisel	Polymer Cap Only	Polymer Cap and Grip
Palm	6380	3214	3648
Wrist	89.5	17.2	7.4
Elbow	3.5	1.8	1.6

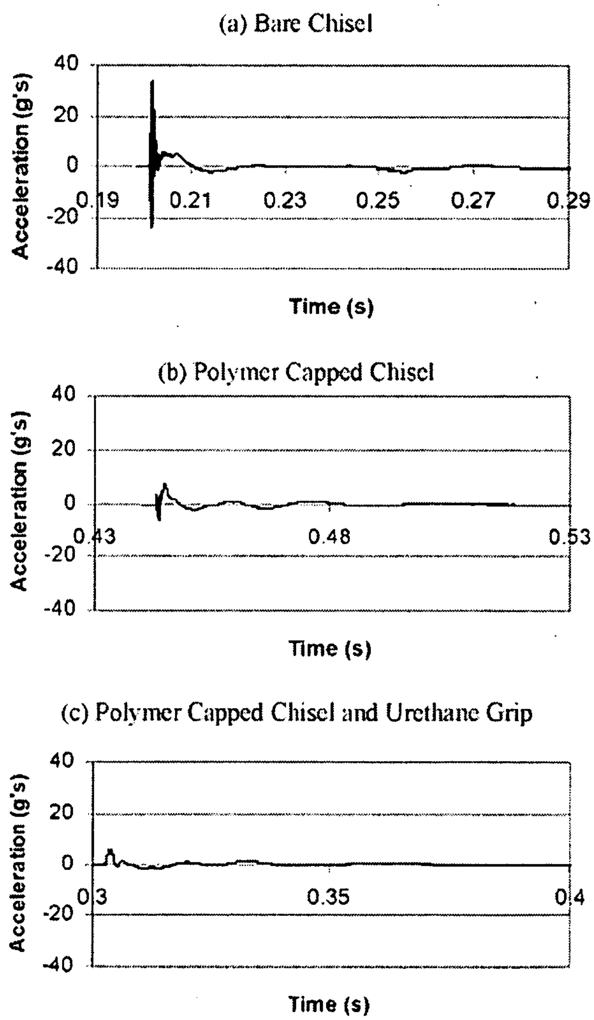

Figure 17. Wrist vibration for a (a) bare, (b) capped, and (c) capped chisel with protective grip.

CONCLUSIONS

Based on the results of this study, the following conclusions have been made:

- The testing methodology was effective in comparing different materials, configurations, etc. for chisel designs that incorporate engineering polymers. The key measures of performance are first the number of hits to fail a standard rod, and second, the chisel force exerted on the test specimen.
- The force transmission characteristics of the hammer-chisel-work system can be modeled with a relatively simple lumped parameter model. Using a series of springs and masses to represent the hammer, chisel, and work, a system model was developed, validated, and used to predict chisel force exerted on the work, and optimize cap thickness and material selection.
- The ideal material for a cap is a polymer with high modulus - to transmit a high force, and high impact strength - to withstand repeated blows.
- Chisel vibration resulting from a hammer impact was generally found to be very high. The addition of the cap significantly reduced vibration levels at the palm, wrist and elbow.
- Chisel noise emission was altered with the addition of the polymer cap. Sound emission around 4500 to 5000 Hz was significantly reduced the addition of the cap.
- Cyclic impact tests of a polymer capped chisel indicate that the tool can be struck thousands of times without failure or undo wear. The effect of off-center and missed hits are currently being investigated.
- Performance of capped chisels is somewhat lower than bare chisels. However, this effect can be essentially eliminated by using a sharper chisel tip angle.
- Polymer capped chisels have several significant performance advantages: reduced operator discomfort due to hand-arm mechanical shock, reduced noise, and less danger from flying metal fragments.

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